METALLURGY IN NUMISMATICS 6

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Mines, Metals, and Money Ancient World Studies in Science, Archaeology and History

EDITED BY

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PREFACE

The papers in this volume in part stem from a conference that was conceived and organised by the Australian Centre for Ancient Numismatic Studies (Macquarie University) and the Epigraphical and Numismatic Museum, Athens. The conference, held at the Iliou Melathron in Athens from 20-22 April, 2015, was entitled 'Mines, Metals and Money in Attica and the Ancient World'. One of its goals was to survey the applications and current state of non-destructive metallurgical analyses in Greek numismatic study. In recent years, progress in these areas has been rapid; and as laboratory instrumentation and techniques have continued to multiply and expand, the topic could not be more timely. The other work that the conference and now this volume addresses is the renewed interest of geologists and archaeologists in further exploiting the evidence on the ground for reconstructing the silver mining and processing industries in Southeastern Attica and Northern Greece. Accompanying these studies are papers from the staff of the Numismatic Museum on the museum's program of testing new acquisitions and on the study of two hoards excavated in Athens.

Altogether, the articles trace precious metal in the Greek world from the extraction of ore in antiquity to museum artifacts of today. Expanding on previous volumes of the Royal Numismatic Society's *Metallurgy in Numismatics* series, the present contributions range from numismatic metallurgy in its traditional laboratory context to metallurgy in the broader, historical sense of ancient metal working in general. In what is probably the most significant achievement, a core of the papers present abundant, fresh evidence for the tremendous scale of long-distance trade in silver from a handful of sources in the Aegean to the great number of Greek city-states around the Mediterranean that began to coin in the late archaic period, including even the cities of Southern Italy and Sicily.

While this volume will be welcomed for its many such findings, its value rests also on the editors' foresight that by inviting these contributions and bringing them together in one place, the studies will become more accessible and prominent than if they had been published separately.

J. H. KROLL

FOREWORD

As Director of the Numismatic Museum at Athens, I am proud of our longstanding numismatic and scientific collaboration with the Australian Centre for Ancient Numismatic Studies (ACANS) at Macquarie University, Sydney. Many Australian researchers, including the two editors of this volume, have spent extensive periods researching at the museum over many years to our mutual benefit. Together we organised the major international conference entitled *Mines, Metal and Money in Attica and the Ancient World* hosted at the museum from 20-22 April, 2015 which formed the genesis of this volume.

The themes of the conference focused on archaic Greek coinage, methods of mining precious metals, and on the historical and institutional framework of the Archaic period in which the conventions for the organisation and control of mining were developed, and through which the commercial distribution of precious metals was carried out. The conference themes also embraced studies of coin production, and technological and research methods for the analysis and conservation of metals that reliably help authenticate ancient coins. In these themes the conference successfully brought together scientists from all over the world.

At the end of the Conference, the temporary exhibition, *When Silver was Born. Archaic Coinage of Athens, Mines, Metals and Coins*, was inaugurated. The exhibition was displayed in the Great Gallery of temporary exhibitions of the Iliou Melathron, the Library of Heinrich Schliemann, on 28 May 2015. It took as its subject the coinage of the Archaic period, an era during which profound changes occurred in politics, the arts, and in society more generally. The exhibition, which was the conclusion of the very fruitful co-operation of our Museum with our colleagues from Australia, exhibited 263 artifacts, most of them for the first time. The objects displayed included acquisitions by Museums and Ephorates of Antiquities, and objects from the Collection of the Alpha Bank. We thank and acknowledge the Alpha Bank for sponsoring the exhibition, and the Australian Research Council of the Australian Government for sponsoring the Conference.

GEORGE KAKAVAS

5. THE EXPLOITATION OF THE ARGENTIFEROUS ORES IN THE LAVREOTIKE PENINSULA, ATTICA, IN ANTIQUITY: SOME REMARKS ON RECENT EVIDENCE

Eleni Andrikou

To the memory of Evangelos Kakavogiannis

ABSTRACT

The Lavreotike peninsula, the southeastern part of Attica which is rich in argentiferous ores, evolved to a great mining area during the Classical period, enabling the city-state of Athens to become a leading power. The process of extracting ores and producing silver is summarized. Recent relevant finds from the Mesogeia area, dating to the Early Bronze Age (EBA), are emphasized. They demonstrate that mining and metallurgy started in Lavreotike as early as the beginning of the third millennium BC or the end of the fourth millennium BC. Some new interpretations concerning the metallurgical procedure during the Classical period are also discussed.

Understanding ancient mining and metallurgy needs a multifaceted approach, combining the study of the archaeological relics and inscriptions, the ancient literature, the geology of the area and the technology of metalworking. Ancient mining in Laurion area has been the object of study from the beginning of the nineteenth century (Fig. 1). Interest was intensified when the Hellenic State, after the mid-nineteenth century, explored the possibility of exploiting the ancient slags found all over the area. Within this framework, the mineralogist Andreas Kordellas in 1860 began walking through the area with a view to assessing the profitability of re-exploitation, but he also collected data related to the ancient mining and metallurgy (Kordellas 1894). Thus from the outset, the history of the modern town of Lavrion was connected to the reworking of the ancient slags. The work of E. Ardaillon, *Les mines du Laurium dans l' Antiquité* (1897), is of substantial importance because it treats various aspects of the subject and takes into account relevant previous research. The ancient technology of silver production was studied profoundly by a Professor of Metallurgy in the Polytechnic School,

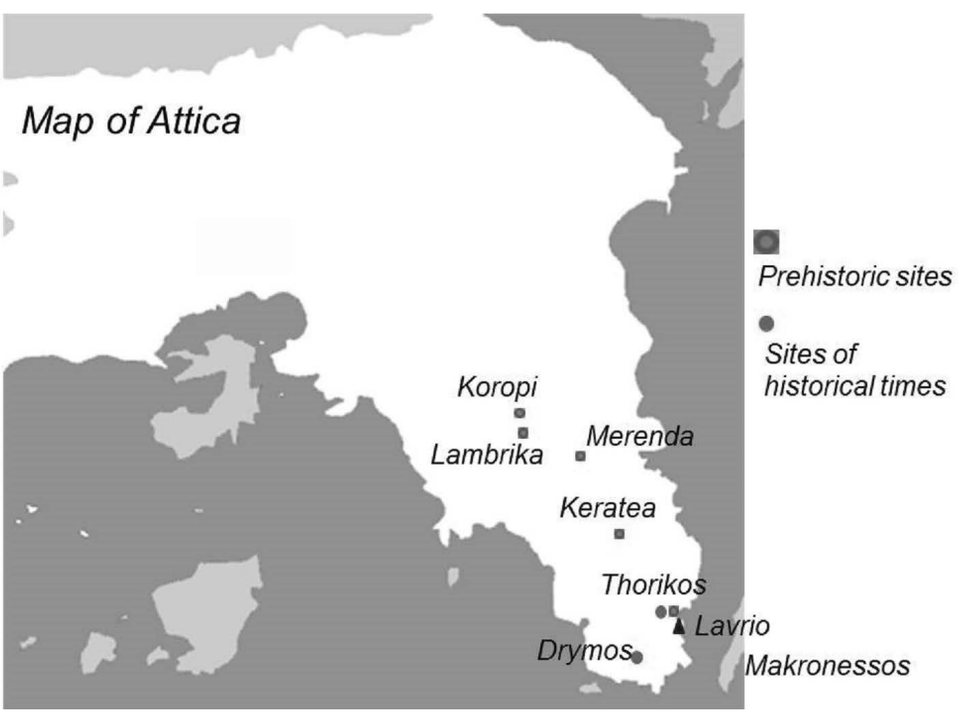

Figure 1. Attica. Sites with metallurgical finds in Lavreotike and Mesogeia

Constantinos Conophagos (Conophagos 1980). The organization of mining operations under the Athenian Democracy, as well as issues of topography and metallurgical technology in the Classical period, were also illuminated through the study of the archaeologist Dr Evangelos Kakavogiannis (Kakavogiannis 2005).

In this paper the results of the relevant research are summarised with an emphasis on the prehistoric mining and metallurgy in Lavreotike and Mesogeia, Attica, as revealed through the finds of the twenty-first century.

The Lavreotike peninsula, the southernmost part of Attica, has been continuously inhabited since prehistoric times (Andrikou 2020). Although human presence is attested in the Palaeolithic era at the Kitsos cave on the Megalo Rimbari mound, systematic habitation started in the Neolithic period after a gap of thousands of years, according to the finds (Lambert 1981, 710–716; Lohmann *et al.* 2002). Thorikos was already a significant centre in the second millennium BC, apparently due mainly to mining (Gill 2010), as the monumental Mycenaean tombs on Velatouri hill prove (Staes 1893; Laffineur 2010).

Following the state reorganization by Kleisthenes in 507 BC, seven demes were created in the Lavreotike (Whitehead 1986). The coastal deme of Anaphlystos (modern Anavyssos) and the mountainous deme of Phrearrioi (*phrear* = well, shaft) were more densely inhabited. From the Thorikos deme, part of the habitation *insulae*, the theatre, temples and cemeteries have come to light, as well as ore washeries and mining galleries on the west slope of Velatouri hill; the excavations of these sites are described in the reports of Belgian archaeologists (Mussche 1998). The deme of Sounion extended in the area north and north-east of the cape, where the fortress and village, the sanctuary of Poseidon as well as the nearby sanctuary of Athena were established (Oikonomakou-Salliora 2004, 41–127). This fortress was of crucial importance for the city-state of Athens, for it controlled the crossing to and from the Aegean Sea, as well as the hinterland with its argentiferous deposits. The famous Athenian tetradrachms were minted from Laurion silver. A hoard of 282 Athenian tetradrachms dating to the end of the fourth century BC was unearthed at Thorikos (Bingen 2010).

In the geological stratigraphy of Lavreotike, layers of schist (Kakavogiannis 2005, 92, fig. 2, S1, S2) alternate with layers of marble (M1, M2). Where these layers contact one another, the mineral deposits with metalliferous veins appear (Conophagus 1980, 156–160, fig. 9–1; Morin and Photiades 2005, 331–334). The upper 'first contact' lies near the soil surface and the lowest, the 'third contact', at a depth of nearly 100 m (Kakavogiannis 2005, 92).

Mining and metallurgical procedures for the production of silver comprised, at least from the sixth century BC onwards, the following stages:

- Extraction of the argentiferous ore.
- Cleansing of the ore through the removal of the barren elements, in order that the silver output is increased during the melting operation. The cleansing was achieved by washing the ore after crushing and grinding it.
- Smelting of the argentiferous ore to extract argentiferous lead.
- Smelting of the argentiferous lead (cupellation) to separate the silver from the lead. Lead oxide, called 'litharge' in antiquity (*λιθάργυρος*) comes as a by-product during cupellation.

The shape of the litharge ingots is the result of the method applied to remove the lead from the melted argentiferous lead in the cup, so that pure silver can be collected (Conophagus 1980, 305–330).

Exploitation of the metalliferous deposits pertaining to the first contact goes back to the prehistoric period (Gale *et al.* 2008; Kakavogianni *et al.* 2008; Gale and Stos-Gale 1982). Apparently, it continued and was intensified from the sixth century BC and into the Classical period (fifth–fourth centuries BC). Then it gradually declined and during the Roman and early Christian times (second BC–sixth AD centuries) mining became sporadic and of small scale (Oikonomakou-Salliora 2004, 143–144, Mussche 2006, 226).

Figure 2. Lambrika. The EH I metallurgical workshop (Archive: EphA East Attica)

Pottery found inside mine gallery 3 at Thorikos indicates that argentiferous ore was extracted in Early Helladic (EH) III phase (end of the third millennium BC), and perhaps already by the end of the previous phase, EH II (Spitaels 1984). Mining can reasonably be assumed to have started earlier, in the Final Neolithic (fourth millennium BC), by extracting the deposits of the first contact visible on the soil surface. This usually occurred on hills, such as Rimbari, Souvlero, Ovriokastro, where small mine galleries are observed (Kakavogiannis and Kakavogianni 2001, 56–57). Early ore extraction seems more probable since the EH I (3200–2800 BC) metallurgical workshop at Lambrika, Koropi (Fig. 2) was unearthed and published (in preliminary form) by Kakavogianni (Kakavogianni 2001–2004; Kakavogianni *et al.* 2009b, 241–244). The workshop consists of a large, nearly circular pit with five cavities (diam. 0.19 m and depth 0.10 m) on both sides, lined with a whitish material. In a second pit, immediately to the north-east, more than 1000 pieces of litharge ingots as well as a whole one had been discarded together with other objects, mostly pottery and millstones. The litharge ingots (Fig. 3) are bowl-shaped with 10 regular cavities arranged in rows of three – four – three on the upper surface. Chemical analysis has shown that they contain fluorine and copper, which characterise the argentiferous ores of Lavreotike (Kakavogianni *et al.* 2006). The ingots are not of pure lead oxide, since silica, aluminum oxide, calcium oxide and magnesium oxide were detected in amounts of 10–15% (Douni *et al.* forthcoming). A similar chemical synthesis was detected in the material used for the lining of the workshop cavities. The archaeological and archaeometric studies of the evidence have concluded that it is a cupellation workshop (Kakavogianni *et al.* 2008). Cupellation, the final stage of the metallurgical procedure for silver and lead production, requires advanced knowledge and experience in metallurgy. Although the exact procedure of cupellation at Lambrika remains unknown, it seems most probable that the litharge bowls were formed when lead oxide was absorbed by an aluminosilicate mass placed inside the cavities of the workshop (Kakavogianni *et al.* 2006, 81–82).

Figure 3. EH litharge ingots from Lambrika. (Archive: EphA East Attica)

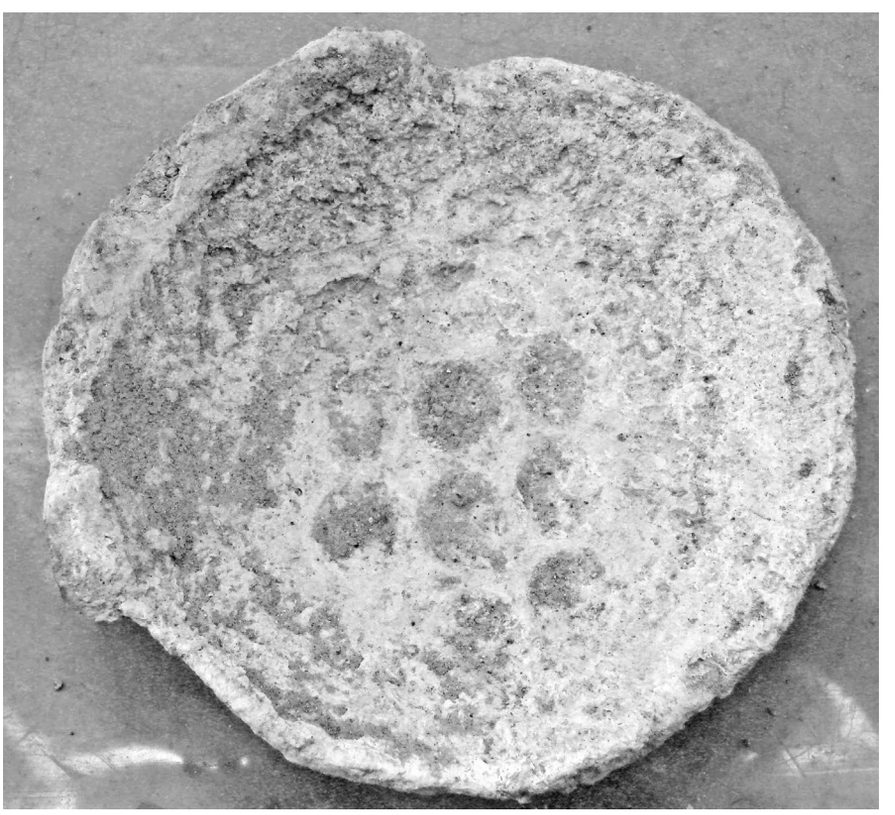

Figure 4. Intact EH litharge bowl from Veniza-Zapani, Keratea. (Archive: EphA East Attica)

Similar litharge ingots but in smaller numbers have been found at various EH sites in the Lavreotike, such as Makronessos, Kalme hill, and Mokriza (Lambert 1972; Spitaels 1982a; Spitaels and Demolin 1993; Tsaravopoulos 1997; Parras 2010) and in the Mesogeia, at Merenda and Koropi (Kakavogianni and Douni, 2001–2004; Kakavogianni *et al.* 2009a, 165, 171, 172). However, in two adjacent sites in the Veniza–Zapani area of Keratea (Andrikou 2007) a significant number of litharge ingots, about 700 and 220 respectively (Fig. 4) were found. These quantities match those from the previously mentioned metallurgical workshop at Lambrika. Although remains of a workshop were not attested here, the particular features and dispersal of the litharge bowls suggest that they should be identified as material rejected after cupellation, as is the case at Lambrika. The fact that the intermediate stages of ore processing, from the extraction to the cupellation, are not detectable at Lambrika and Veniza–Zapani, leads to the conclusion that they took place near the mining area and that only argentiferous lead reached the workshops. The small number of litharge ingots at the other sites mentioned suggests secondary procedures, in order to produce lead. But such procedures are little known from the Early Bronze Age Aegean and this hypothesis is not supported by other finds, *e.g.* slags.

The litharge bowl with cavities on top, the main type in Attica, is apparently a local feature (Douni *et al.* forthcoming), since it is not found at other sites. At Limenaria on Thasos and Akrotiraki on Siphnos litharge bowls bear no cavities on top (Papadopoulos 2008); this type is rare in Attica. In any case, metallurgy was undoubtedly exercised at several EH settlements in E-SE Attica. At the extensive EH II settlement at Koropi, besides a few litharge ingots, lead masses were found, as well as evidence, such as clay moulds (Andrikou 2013, 179–180, fig. 17) for bronze metallurgy (Gale *et al.* 2008). Metallurgy of silver and lead continued in the Middle Helladic (MH) period, as is shown by the litharge ingots from Velatouri hill, Thorikos and from Velatouri hill, Keratea (Servais1967, 22–23; Kakavogianni and Douni 2010, 202). This is also true for the Late Helladic (LH) period, since silver and lead artifacts found in Athens, the Perate cemetery and at other sites, were manufactured from Lavrion metals (Gale and Stos-Gale 1982, 484–485), and as ore was mined in the mine gallery 3 at Thorikos in the LH IIIC phase (Spitaels 1982b; Mountjoy 1995).

The cupellation workshop at Lambrika and the great number of litharge bowls from layers securely dated to the EH and MH periods disprove the suggestion, based on two stray finds, that litharge bowls were minting cups (Conophagos *et al.* 1976, 12–16, figs 8–10; Conophagos 1980, 370f., fig. 16–4 and 5). The long-lasting ore extraction in the Laurion region resulted in the exhaustion of the first contact, but it also brought about the acquisition of knowledge and experience in searching for and mining argentiferous ores at a greater depth, including the successful handling of ventilation in vertical shafts and galleries (Kakavogiannis 2005, 100–103, pl. 3–4; Morin and Photiades 2005, 335–338; Morin *et al.* 2012). It is not possible to date the progression in detail, but it is believed that the miners reached the deepest third contact at the end of sixth or the beginning of fifth century BC, when the first ore washeries also appeared (Kakavogiannis 2005, 244–253).

But for all the improvements in mining technology noted above, the increase in the silver output could not have been realised unless the ore washery had been invented (Kakavogiannis 2001, 365–368). Ore cleansing was fundamental if a larger quantity of silver was to be smelted. It was accomplished by using water to remove the unwanted rock and earth that was lighter than the argentiferous ore (galenite or cerussite). Since the Lavreotike is an arid area, the washeries were installed in the valleys (characteristic of the terrain in the area) to benefit from the flow of streams which do not last the whole year. The unceasing activity of the workshops was secured by the washeries. Their operation relied on the gathering, use and recycling of rain water. The main parts of the washery (Fig.5) are the water tank (Δ) and an open conduit system of channels (A) alternating with basins (Φ). The water needed for the ore cleansing flowed from the water tank to the channels and the basins where the rock and earth could eventually

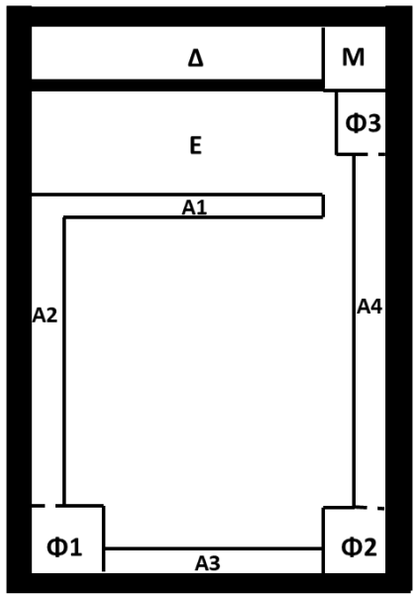

Figure 5. Schematic ground plan of rectangular ore washery, Type 1 (without scale). Classical period

settle on the bottom. The water thus cleaned could be transferred again to the tank and reused. In the Bertsekos valley, precursors of the washeries dating to the Archaic period (sixth century BC) have been revealed (Kakavogiannis 2005, 249–253, fig. 36–38). The arrangement of the main parts of the washeries at the Bertsekos valley indicates experimentation when compared to the standardised rectangular washeries of the Classical period.

The washery was supplied from big open cisterns lined with hydraulic cement (Papadimitriou and Kordatos 1995), where rain water was gathered (van Liefferinger *et al.* 2014) as, for example, at the *Asklepiakon* washery at Souriza valley, the washeries at Agia Triada (Drymos), Souriza valley and the washeries at Michalis mount, Agrileza (Conophagos 1980, 386 fig. 17–1; Jones 1984–85, 111, 123; Kakavogiannis 2001; Kakavogiannis 2005, 225–229, pl. 9–11). A cover of perishable materials protected the water from evaporation (*e.g.* Agia Triada (Drymos) and Souriza) (Kakavogiannis 2005, 226–227, pl. 10α).

Apart from the washery and the cistern the workshop for ore purification comprised the area for crushing the ores, the area for forming the cleaned ore into bricks, storage areas and residential buildings for the personnel and sometimes the owner (*e.g.* the *Asklepiakon* at Souriza valley: Conophagos 1980, 387–388; Oikonomakou-Salliora 2004, 106–108, fig. 95, 96.). The ore extracted from the mines was transferred to the workshop to be crushed on stone tables, grinded in mortars and mills and sieved in order to obtain uniform particle size before washing (*e.g.* Agia Triada (Drymos), Souriza: Kakavogiannis 2005, 220–224, pl. 6–8).

The water tank of the washery was closed in the front with big slabs, carrying a series of holes of a standard height above the floor. According to Conophagos (1980, 224ff), the ores once ground were put in wooden sluices placed in front of each hole and tilted downward to the first channel. As the water flowed through the hole it swept away the earth lighter than the argentiferous ore. However, neither excavation data nor any information from antiquity in texts or images indicates the existence of wooden sluices (Mussche 2006, 226–228; see Lohmann in this volume). Taking this into account as well as the fact that during the washery excavations a great many clay basins came to light (a number not compatible with everyday use), Kakavogiannis (2005, 233–242) suggested another interpretation. The worker put a small quantity of ground ore in the clay basin and filled it partially with water from the tank (which was full of water and had blocked front holes). Then, holding the basin by the two handles, he moved it cyclically causing the water to whirl. The heavy metalliferous grains settled to the bottom, while the lighter earth floated. The impure water was emptied back

into the tank, for the earth to fall to the bottom. After this procedure had been performed several times and the water of the tank became cloudy, the holes were unblocked and the water flowed to the open conduit to be cleaned as described earlier. The mud which gathered gradually in the tank and in the conduit was scooped up with shovels and thrown away. Heaps of such mud, called *plynites* by Kordellas (1888, 27ff.), were found densely scattered all over the mining area of Lavreotike (Kakavogiannis 2005, 232–233, pl.14a). The washed ore, after draining off in the central rectangular area of the washery, was transported to another area to be formed into bricks and dried. 'Briquetting' was indispensable to allow the successful feeding of the ore into the furnace.

Only a few smelting workshops (such as found at Megala Pefka, Ary, Frangolimano and Oxygono at Thorikos, Ormos Asemake at Sounion, Pountazeza) are known in comparison to the number of those for cleansing (Kakavogiannis 2005, 261–264; Tsaimou 2013). At first, argentiferous lead was smelted in furnaces. Then, silver was smelted through the cupellation process in installations known today only from Kordellas' descriptions (1890, 77–78) before they were destroyed during modern exploitation. Cupellation was largely studied and illuminated by Conophagos (1980, 305–330). Pure silver was obtained after the lead oxide floating in the melting cup was poured into another vessel. When it cooled, it solidified and formed a flat litharge ingot. Later on litharge ingots were tubular, since iron rods were used to remove lead oxide from the cup (Kakavogiannis 2005, 273–279, pl. 23).

In the Classical period exploitation was intensified. The evidence of archaeology and especially epigraphy shows that relations between the Athenian state and entrepreneurs were now set out within a very detailed legal framework (Kakavogiannis 2005, 111–214).

The Lavreotike is densely covered with mining shafts and architectural relics of metallurgical workshops (mainly washeries in the valleys) and of residential and burial sites. Few washeries have been excavated and even fewer smelting workshops (which seem to concentrate at the coast). A detailed mapping of the vestiges will require extensive work to remove the vegetation and accumulated earth. Projects such as the mapping of Ari, a Collaboration of the Ephorate of Antiquities of East Attica and the German Archaeological Institute in Athens which has been in progress since 2014 (see Lohmann in this volume), will greatly contribute not only to a better understanding of mining and metallurgical procedures, but also to our knowledge of the spatial and social organisation of the people who lived at this site.

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